Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
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6	
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8	
9	
10	
TOTAL	

AQA

General Certificate of Education
Advanced Level Examination
June 2014

Computing COMP3

Unit 3 Problem Solving, Programming, Operating Systems, Databases and Networking

Tuesday 17 June 2014 9.00 am to 11.30 am

You will need no other materials
You may use a calculator.

Time allowed
- 2 hours 30 minutes

Instructions
A
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The use of brand names will **not** gain credit.
- Question 7(b) should be answered in continuous prose. In this question you will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Answer **all** questions in the spaces provided.

1 **Table 1** lists three situations which involve the transmission of data/information/addresses.

1 (a) For each row in **Table 1**, place a tick in **one** column to indicate whether the transmission is most likely to be serial, most likely to be parallel or could be either serial or parallel.

[3 marks]

Table 1

Situation	Most likely to be Parallel	Most likely to be Serial	Could be either Serial or Parallel
Sending data to a peripheral, such as a printer, that is plugged directly into a computer.			
Transferring memory addresses between the processor and the main memory of a desktop computer.			
Transmitting an email across a WAN from a computer in England to an email server in Scotland.			

1 (b) Data communication often uses a handshaking protocol.

Explain **one** purpose of a handshaking protocol.

[1 mark]

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1 (c) When data is transmitted over long distances, eg via satellites, latency can become a problem.

Explain what latency is.

[1 mark]

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5

2 Regular expressions can be used to search for strings.

2 (a) For each of the following regular expressions, describe the set of strings that they would match.

2 (a) (i) `b*c`

[1 mark]

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.....

2 (a) (ii) `b?c`

[1 mark]

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2 (b) Write a regular expression that matches the letter `b`, followed by zero or more occurrences of the string `cd` followed by either a single letter `e` or the string `fg`.

[2 marks]

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4

Turn over for the next question

3 A computer program stores a list of integers in an array named `List`. The numbers in the array are to be sorted into ascending order so that a particular efficient search algorithm can be used to search for a number.

3 (a) One of the search algorithms in **Table 2** can only be used successfully on a sorted list.

Place **one** tick next to the name of the algorithm that requires a list to be sorted.

[1 mark]

Table 2

Algorithm Name	**Requires Sorted List? (Tick one box)**
Binary search	
Linear search	

3 (b) The pseudo-code for a standard algorithm that can be used to sort the data in the array `List` into order is shown in **Figure 1**. The variable `ListLength` stores a count of the number of items in the array `List`.

Array indexing starts at 1.

Figure 1

```
For OuterPointer ← 2 To ListLength
  CurrentValue ← List[OuterPointer]
  InnerPointer ← OuterPointer - 1
  While InnerPointer > 0 And
        List[InnerPointer] > CurrentValue Do
    List[InnerPointer + 1] ← List[InnerPointer]
    InnerPointer ← InnerPointer - 1
  EndWhile
  List[InnerPointer + 1] ← CurrentValue
EndFor
```

Complete the empty (unshaded) cells in the trace table (**Table 3**) for an execution of the algorithm in **Figure 1** when the array `List` contains the values `9`, `8`, `5` and `6` in that order.

[3 marks]

Table 3

List Length	Outer Pointer	Current Value	Inner Pointer	List [1]	List [2]	List [3]	List [4]
				9	8	5	6
4	2		1				
			0				
	3		2				
			1				
			0				
	4		3				
			2				
			1				

3 (c) In the trace table (**Table 3**), when the variable `OuterPointer` contains the value `2` and then `3`, the value of the variable `InnerPointer` decreases to `0`. When `OuterPointer` contains `4`, `InnerPointer` stops decreasing when it reaches the number `1`.

Explain why `InnerPointer` does not decrease to `0` when `OuterPointer` contains `4`.

[1 mark]

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Question 3 continues on the next page

3 (d) Tick **one** box in **Table 4** to indicate the correct Order of **Time** Complexity of the standard algorithm in **Figure 1**.

[1 mark]

Table 4

Order of Time Complexity	Tick one box
O(n)	
$O(n^2)$	
$O(2^n)$	

3 (e) State the name of the standard algorithm that is represented by the pseudo-code in **Figure 1**.

[1 mark]

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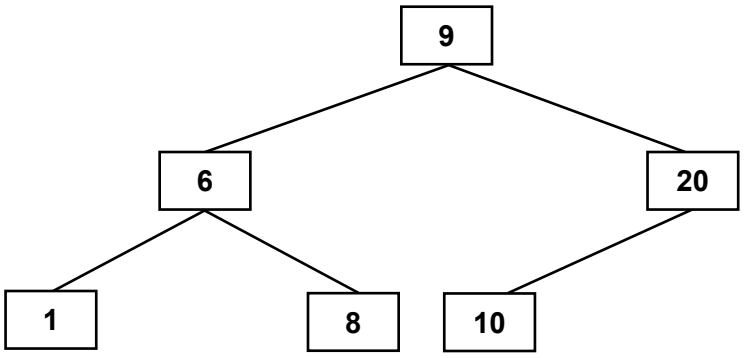
3 (f) Instead of storing a list of numbers in an array as in 3(b), the numbers could be stored in a binary search tree. This would also enable efficient searching.

The numbers 9, 6, 1, 8, 20 and 10 are put into a binary search tree in that order. **Figure 2** shows this binary search tree.

Figure 2



3 (f) (i) A search of the binary tree is performed for the number 8.

List the numbers, in the order that they would be checked, for the search to determine that the number 8 **is present** in the tree.

[1 mark]

.....

3 (f) (ii) A search of the binary tree is performed for the number 11.

List the numbers, in the order that they would be checked, for the search to determine that the number 11 **is not present** in the tree.

[1 mark]

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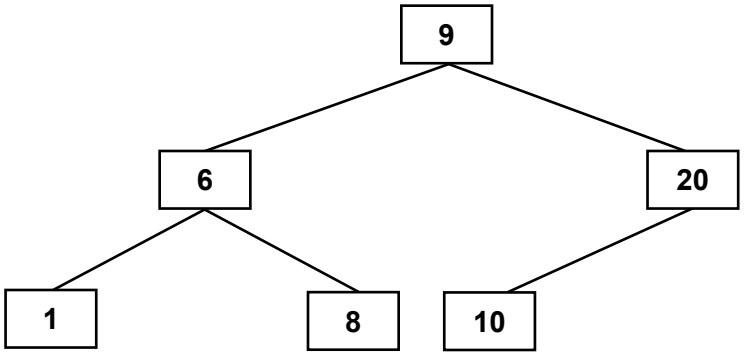
3 (g) The numbers 4, 5 and 3 are to be added into the binary search tree, in that order.

Figure 3 below is an identical copy of **Figure 2**.

Complete **Figure 3** below to show the binary search tree from **Figure 2** after the extra numbers have been added into it.

[2 marks]

Figure 3

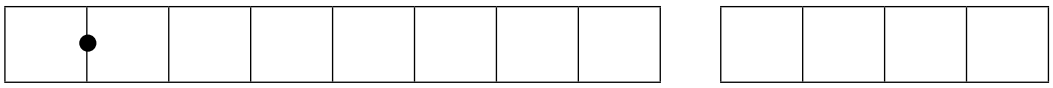


11

4 A normalised floating point representation uses an 8-bit mantissa and a 4-bit exponent, both stored using **two's complement format**.

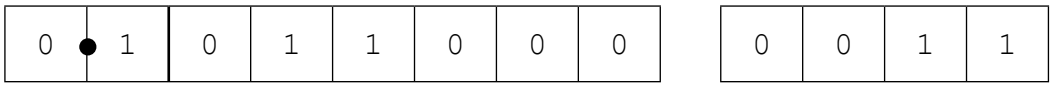
4 (a) In binary, write the largest positive number that can be represented using this normalised floating point system in the boxes below:

[2 marks]



Mantissa Exponent

4 (b) This is a floating point representation of a number:



Mantissa Exponent

Calculate the denary equivalent of the number. Show how you have arrived at your answer.

Working .....

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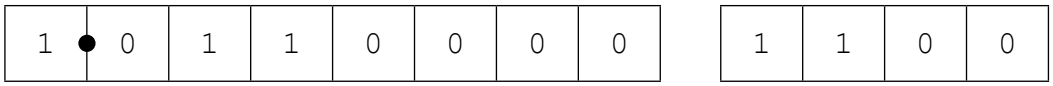
[1 mark]

Answer .....

[1 mark]

4 (c) This is a floating point representation of a number:



Mantissa Exponent

Calculate the denary equivalent of the number. Show how you have arrived at your answer.

Working .....

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[1 mark]

Answer .....

[1 mark]

4 (d) Write the normalised floating point representation of the **negative** denary value −108 in the boxes below. Show how you have arrived at your answer.

Working .....

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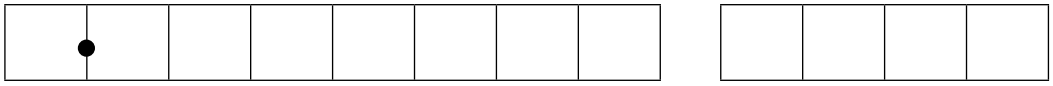
[2 marks]

Answer



Mantissa Exponent

[1 mark]

4 (e) (i) In the context of floating point representation, explain what overflow is.

[2 marks]

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4 (e) (ii) **Table 5** below contains descriptions of operations which may or may not cause an overflow error when they are carried out with a floating point representation.

Place **one** tick next to the operation that may cause overflow.

[1 mark]

Table 5

Operation	**May cause overflow? (Tick one box)**
Subtracting a very small number from a large number.	
Dividing a large number by a very small number.	
Multiplying a large number by a very small number.	

12

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

5 A computer program is being developed to play a card game on a smartphone. The game uses a standard deck of 52 playing cards, placed in a pile on top of each other.

The cards will be dealt (ie given out) to players from the top of the deck.

When a player gives up a card it is returned to the bottom of the deck.

5 (a) Explain why a queue is a suitable data structure to represent the deck of cards in this game.

[1 mark]

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5 (b) The queue representing the deck of cards will be implemented as a **circular** queue in a fixed size array named `DeckQueue`. The array `DeckQueue` has indices running from `1` to `52`.

Figure 4 shows the contents of the `DeckQueue` array and its associated pointers at the start of a game. The variable `QueueSize` indicates how many cards are currently represented in the queue.

Figure 4

DeckQueue

Index	Data
[1]	10-Hearts
[2]	2-Spades
[3]	King-Hearts
[4]	Ace-Clubs
. . .	
[52]	8-Diamonds

```
FrontPointer = 1
```

```
RearPointer = 52
```

```
QueueSize = 52
```

5 (b) (i) Ten cards are dealt from the top of the deck.

What values are now stored in the `FrontPointer` and `RearPointer` pointers and the `QueueSize` variable?

[1 mark]

`FrontPointer` **=** ..... `RearPointer` **=** .....

`QueueSize` **=** .....

5 (b) (ii) Next, a player gives up two cards and these are returned to the deck.

What values are now stored in the `FrontPointer` and `RearPointer` pointers and the `QueueSize` variable?

[1 mark]

`FrontPointer` **=** ..... `RearPointer` **=** .....

`QueueSize` **=** .....

5 (b) (iii) Write a pseudo-code algorithm to deal a card from the deck.

Your algorithm should output the value of the card that is to be dealt and make any required modifications to the pointers and to the `QueueSize` variable.

It should also cope appropriately with any situation that might arise in the `DeckQueue` array whilst a game is being played.

[6 marks]

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5 (c) The program for the card game will be an event-driven program.

Explain what it means for a program to be described as event-driven.

[2 marks]

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5 (d) The card game program will interact with the operating system on the smartphone.

Describe **two** differences between the operating system that is installed on the smartphone and an operating system that would be used on a desktop computer.

[2 marks]

Difference 1 .....

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Difference 2 .....

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13

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

6 A government agency is responsible for storing information about vehicles and their owners. Each vehicle that is driven must be registered with this agency. Vehicles must be insured to be driven, so the agency also keeps a record of vehicle insurance policies.

Details of the vehicles, owners and insurance policies are stored in a relational database using the following three relations:

```
Vehicle(RegistrationNumber, OwnerID, Manufacturer,
Model, Colour, EngineSize, DateRegistered)

Owner(OwnerID, Title, Forename, Surname, HouseNumber,
Street, Town, Postcode)

Insurance(PolicyNumber, RegistrationNumber, DateStarted,
PolicyType, ExcessAmount)
```

In this system, the following restrictions apply to some attributes:

- RegistrationNumber: a mixture of exactly 7 letters and numbers, eg MA11FXB
- EngineSize: a whole number value representing the capacity of the engine, eg 1597
- PolicyType: can be either 'Comprehensive' or 'Third Party' and nothing else
- ExcessAmount: a monetary value, eg 100

6 (a) Complete the following Data Definition Language (DDL) statement to create the Insurance table, including the key field.

[3 marks]

```
CREATE TABLE Insurance (
```

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.....)

6 (b) The owner of the vehicle with registration number DF24JUT has had his car repainted so that its colour is now pink.

Complete this SQL statement to update the data in the Vehicle table to reflect this change.

[2 marks]

UPDATE .....

SET .....

WHERE .....

6 (c) A police officer is following a car with registration number AB72XHC. She wants to use the computerised system to check some details about the car and its owner.

Write an SQL query that could be used to retrieve the Model and Colour of the car and the Forename and Surname of the car's owner.

[4 marks]

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Question 6 continues on the next page

6 (d) The police officer requests the information using a hand held terminal that connects to the Internet. She types the vehicle registration number into a form on a secure web page and the details about the car and owner are then displayed in the web browser on the terminal.

A server-side script is used to search for the required information.

6 (d) (i) Explain what a server-side script is.

[2 marks]

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6 (d) (ii) The server-side script includes the statement:

```
RegNo = Request("RegistrationNumber")
```

Explain what this statement does when executed.

[2 marks]

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6 (d) (iii) The server-side script includes the statement:

```
Response.Write("Owner is " + Forename + " " + Surname)
```

Explain what this statement does when executed.

[2 marks]

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The definitions of the three relations in the database on page 16 are repeated here so that you can answer Question **6 (e)** on this page without having to turn back in the question booklet.

```
Vehicle(RegistrationNumber, OwnerID, Manufacturer,
Model, Colour, EngineSize, DateRegistered)

Owner(OwnerID, Title, Forename, Surname, HouseNumber,
Street, Town, Postcode)

Insurance(PolicyNumber, RegistrationNumber,
DateStarted, PolicyType, ExcessAmount)
```

6 (e) The database is to be extended to store information about vehicle safety certificates. Each year, a vehicle must be taken to a garage where it will be tested. If the vehicle passes the test, a certificate will be issued. Each certificate will have a unique Certificate Number. Certificates will last for 12 months so the date that a certificate is issued must be recorded, as must the name of the garage that issued the certificate.

The database must keep a record of all the certificates that have been issued for each vehicle. For a particular vehicle this will include the current certificate together with any certificates that have been issued in the past.

Explain how you would change the design of the database so that the information about safety certificates can be stored.

[3 marks]

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18

Turn over for the next question

7 A computer program is being developed to allow commuters to plan journeys on the London Underground railway network which connects together over 250 stations.

The program needs to store a representation of the network so that the **shortest route** (ie shortest distance) between any two stations can be found.

Figure 5 is a map of central London, showing the location of ten of the stations on the London Underground. The locations of the underground railway lines are not shown. Note that nine of the stations are indicated by the symbol ⊖ but Charing Cross has a different symbol ⇌ because it is a combined underground and overground station.

Figure 5

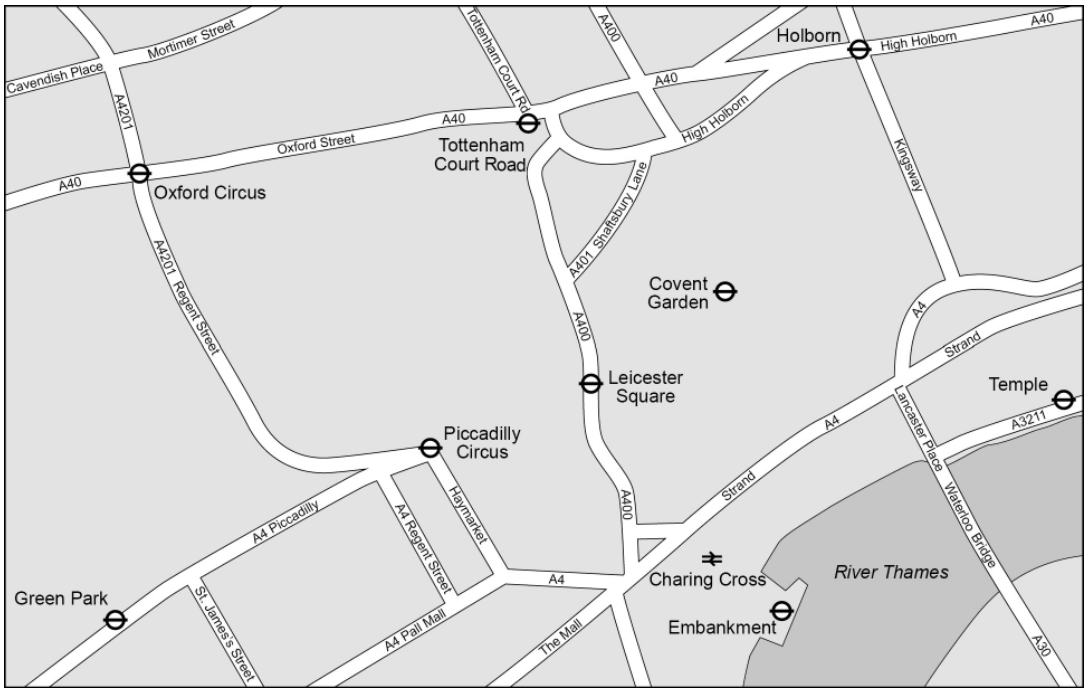
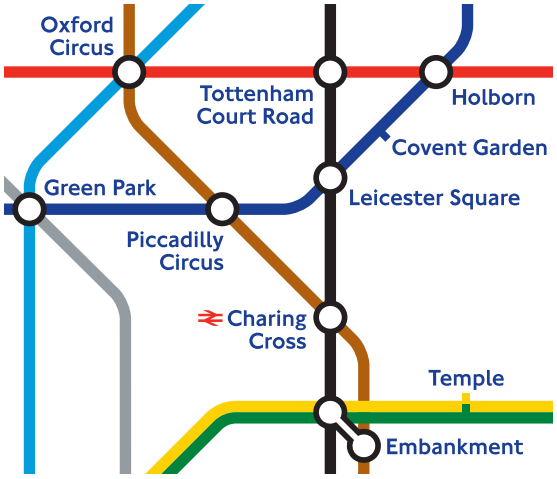


Figure 6 is a map of part of the underground railway network, showing the same ten stations. This map does not show the streets above ground but instead shows the underground railway lines that connect the stations together.

Figure 6



Section of Tube map reproduced by kind permission of Transport for London.
Registered user number 13/E/2438/P

Figure 6 can be used in conjunction with a table of distances between adjacent stations to calculate the shortest route between any two stations on the network.

The map of the entire underground railway network (**not** just the parts shown in **Figure 5** and **Figure 6**) together with the full table of distances can be represented logically as a graph.

Question 7 continues on the next page

7 (a) The representation of the underground railway network as a graph is an abstraction.

Explain what an abstraction is.

[1 mark]

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7 (b) Write a detailed description of:

- how the underground railway network and table of distances could be represented as a graph, **and**,
- how this representation could be implemented as either an adjacency matrix **or** an adjacency list (describe **one** of these alternatives only), using array(s) in a programming language that does not have a built-in data structure for graphs.

Your implementation should store all the details that are required to calculate the shortest distance between any two stations, but you do not need to describe how the shortest distance would be worked out.

In your answer you will be assessed on your ability to use good English, and to organise your answer clearly in complete sentences, using specialist vocabulary where appropriate.

You may use diagrams to help clarify your description, but as you are being assessed on your ability to use good English, you must ensure that all diagrams are fully explained.

[8 marks]

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Do not write outside the box

9

Turn over ▶

8 An event-driven, object-oriented programming language lets the programmer create a Graphical User Interface (GUI) from components such as forms and buttons. The components of the GUI are implemented using a class hierarchy and inheritance.

8 (a) Explain what is meant by inheritance.

[1 mark]

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8 (b) One GUI component is a **Selector**. Selectors come in two different types: **ComboBox** and **ListBox**.

Selector Type	Description
ComboBox	A combo box lets the user make an input either by typing into the box **or** by picking a single item from a list.
ListBox	A list box lets the user select options from a list. The user cannot type into a list box. There are two different types of list box: • **SingleSelectionListBox**: The user can only select one item from a list. Whenever an item is selected, the previously selected item is deselected. • **MultipleSelectionListBox**: The user can select one or more items from a list. Whenever an item is selected, it is added to the list of selected items.

Draw an inheritance diagram for the classes: Selector, ComboBox, ListBox, SingleSelectionListBox and MultipleSelectionListBox.

[3 marks]

Question 8 continues on the next page

8 (c) The **Selector** class has data fields **Items** and **NumberOfItemsInList**:

- **Items**: an array that stores the list of strings that will appear in the selector.
- **NumberOfItemsInList**: a number that indicates how many items there are in the selector.

It also has a procedure that the programmer can call to add an item to the list of strings (**AddItemToList**) and a procedure that is called by the operating system whenever the user selects an item from the list (**SelectItemFromList**).

The **Selector** class does not include a procedure to display the items in the list as the way items are displayed is different for each type of selector.

The class definition for **Selector** is:

```
Selector = Class
             Public
               Procedure AddItemToList
               Procedure SelectItemFromList
             Private
               Items: Array of String
               NumberOfItemsInList: Integer
           End
```

A class is to be created for the **ComboBox** type of selector.

The **ComboBox** class needs the following additional data fields:

- **TextTyped**: Stores the characters that have been typed by the user if they have made their input by typing rather than picking an option from the list.
- **SelectedItemNumber**: Stores the position in the list of the item that has been selected by the user, if one has been selected.
- **AllowNonListInputs**: A True or False value that indicates whether the user should be allowed to type in text that is not one of the items in the list.

The class will need to implement the operation of selecting an item from the list differently from the way the **Selector** class implements this operation, but the operation of adding an item to the list will be implemented in the same way by both of these classes.

The class must provide subroutines to:

- display the combo box
- respond to the operating system's notification of a key press
- return the text that has been typed in
- return the selected item number
- set the value of **AllowNonListInputs** flag to True or False, to indicate whether or not the user is allowed to type text that is not in the list.

Write the class definition for the **ComboBox** class.

[5 marks]

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9

Turn over for the next question

9 A Turing machine has been designed to recognise palindromic binary numbers, ie numbers such as `101` and `0110` that read the same from left to right as from right to left.

The machine has states S_B, S_0, S_1, S_{C0}, S_{C1}, S_L, S_Y and S_N.
S_B is the start state and S_Y and S_N are the stop states.

The machine stores data on a single tape which is infinitely long in one direction. The machine's alphabet is 0, 1 and $\square$, where $\square$ is the symbol used to indicate a blank cell on the tape. The machine will enter state S_Y if the value represented on the tape is a palindromic binary number, otherwise it will enter state S_N.

The transition rules for this Turing machine can be expressed as a transition function δ. Rules are written in the form:

$$\delta(\text{Current State, Input Symbol}) = (\text{Next State, Output Symbol, Movement})$$

So, for example, the rule:

$$\delta\ (S_B, 0) = (S_0\ , \square, \rightarrow)$$

means:

IF the machine is currently in state S_B AND the input symbol read from the tape is 0

THEN the machine should change to state S_0, write a blank symbol ($\square$) to the tape and move the read/write head one cell to the right

The machine's transition function, δ, is defined by:

$$\begin{array}{lll}
\delta\ (S_B, 0) = (S_0, \square, \rightarrow) & & \delta\ (S_{C0}, 0) = (S_L, \square, \leftarrow) \\
\delta\ (S_B, 1) = (S_1, \square, \rightarrow) & & \delta\ (S_{C0}, 1) = (S_N, 1, \leftarrow) \\
\delta\ (S_B, \square) = (S_Y, \square, \rightarrow) & & \delta\ (S_{C0}, \square) = (S_Y, \square, \rightarrow) \\
 & & \\
\delta\ (S_0, 0) = (S_0, 0, \rightarrow) & & \delta\ (S_{C1}, 0) = (S_N, 0, \leftarrow) \\
\delta\ (S_0, 1) = (S_0, 1, \rightarrow) & & \delta\ (S_{C1}, 1) = (S_L, \square, \leftarrow) \\
\delta\ (S_0, \square) = (S_{C0}, \square, \leftarrow) & & \delta\ (S_{C1}, \square) = (S_Y, \square, \rightarrow) \\
 & & \\
\delta\ (S_1, 0) = (S_1, 0, \rightarrow) & & \delta\ (S_L, 0) = (S_L, 0, \leftarrow) \\
\delta\ (S_1, 1) = (S_1, 1, \rightarrow) & & \delta\ (S_L, 1) = (S_L, 1, \leftarrow) \\
\delta\ (S_1, \square) = (S_{C1}, \square, \leftarrow) & & \delta\ (S_L, \square) = (S_B, \square, \rightarrow)
\end{array}$$

9 (a) This Turing machine is carrying out a computation. The machine starts in state S_B with the string 101 on the tape. All other cells contain the blank symbol, $\square$ (not shown). The read/write head is located at the left hand symbol of the string and is indicated with an upward arrow.

Trace the computation of the Turing machine, using the transition function δ.

Show the contents of the tape, the current position of the read/write head and the current state as the input symbols are processed.

The initial configuration of the machine has been completed for you in step 1.

[5 marks]

1. | 1 | 0 | 1 | | | | ... | | S_B | State |

2. | | | | | | | ... | | | State |

3. | | | | | | | ... | | | State |

4. | | | | | | | ... | | | State |

5. | | | | | | | ... | | | State |

6. | | | | | | | ... | | | State |

7. | | | | | | | ... | | | State |

8. | | | | | | | ... | | | State |

9. | | | | | | | ... | | | State |

10. | | | | | | | ... | | | State |

11. | | | | | | | ... | | | State |

9 (b) The three rules shown below are part of the machine's transition function.

Explain what effect these three rules, taken together, have on the tape, the read/write head and the state of the Turing machine:

$$\delta (S_0, 0) = (S_0, 0, \rightarrow)$$
$$\delta (S_0, 1) = (S_0, 1, \rightarrow)$$
$$\delta (S_0, \square) = (S_{C0}, \square, \leftarrow)$$

[2 marks]

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9 (c) A Universal Turing machine (UTM) is a special type of Turing machine that can be considered to act like an interpreter.

Explain how a UTM can be considered to be an interpreter.

[2 marks]

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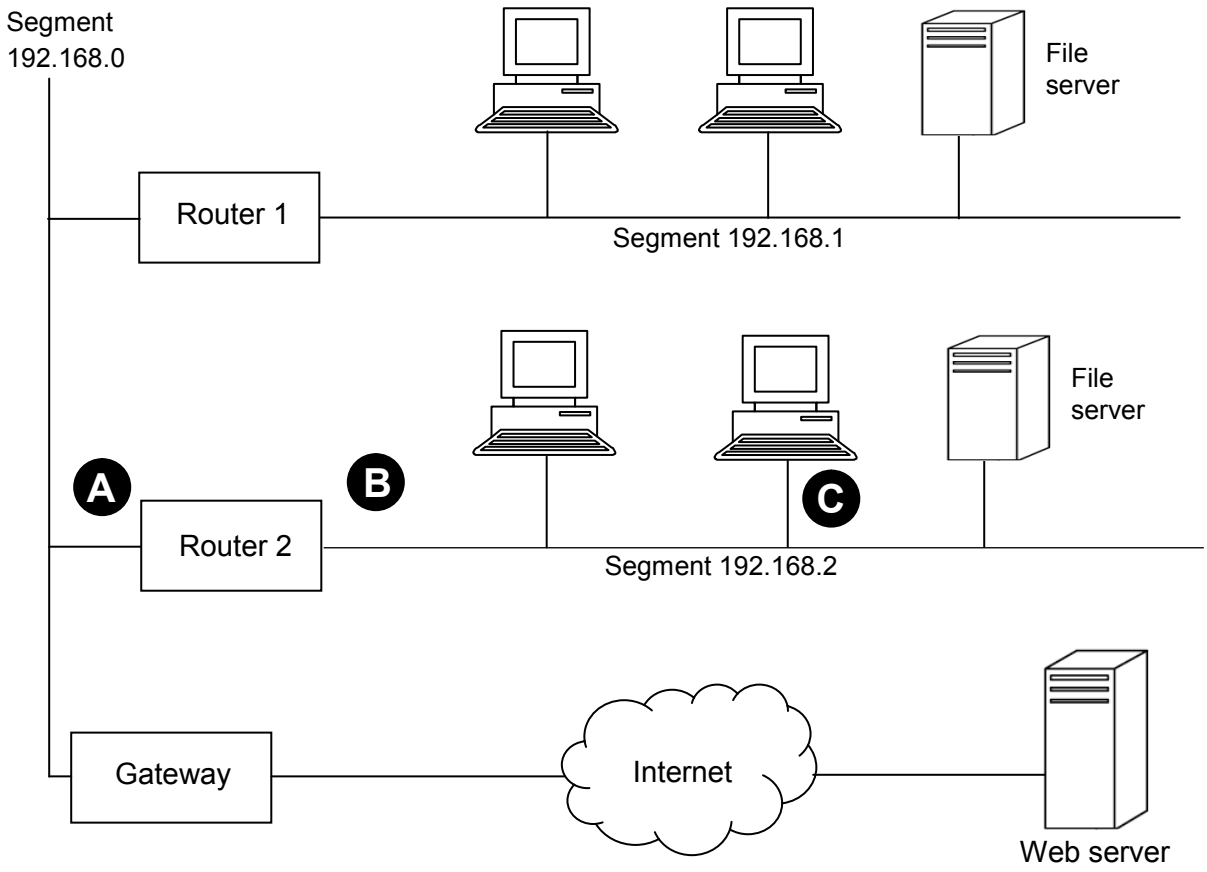
9

10 A company operates a Local Area Network (LAN) which is used by its employees.

Figure 7 shows the topology of the LAN.

Figure 7



10 (a) Suggest suitable IP addresses for:

10 (a) (i) the 'Router 2' port labelled A .....

[1 mark]

10 (a) (ii) the 'Router 2' port labelled B .....

[1 mark]

10 (a) (iii) the network adapter card in the computer labelled C .....

[1 mark]

Turn over ▶

10 (b) The network has been divided into segments.

Explain why networks that use a bus topology are often segmented.

[2 marks]

.....

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10 (c) Previously, employees of the company used word processing and spreadsheet software that was installed locally on each of the individual computers on the network. Now, employees use software with similar features as a service (SaaS). The software runs on a web server and is accessed through the Internet.

10 (c) (i) Explain **two** advantages of using software as a service instead of using software installed locally on individual computers.

[2 marks]

Advantage 1 .....

.....

.....

Advantage 2 .....

.....

.....

10 (c) (ii) Explain **one** disadvantage of using software as a service instead of using software installed locally on individual computers.

[1 mark]

.....

.....

.....

10 (d) One difference between a Local Area Network (LAN) and a Wide Area Network (WAN) is the area that they cover. Describe **two** other differences between a LAN and a WAN.

[2 marks]

Difference 1 .....

.....

Difference 2 .....

.....

10

END OF QUESTIONS

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